

550, 330

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
21 April 2005 (21.04.2005)

PCT

(10) International Publication Number
WO 2005/035462 A1

(51) International Patent Classification: **C04B 5/00,**
C21C 5/28

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(21) International Application Number:
PCT/BR2004/000203

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(22) International Filing Date: 15 October 2004 (15.10.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PI 0306767-0 16 October 2003 (16.10.2003) BR

(81) Designated States (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,
AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN,
CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,
GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE,
KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD,
MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG,
PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM,
TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM,
ZW.

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(84) Designated States (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, GH,
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,
FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI,
SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report

*For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.*

(54) Title: PROCESS OF INERTIZATION (DAMPENING) OF STEEL MAKING SLAG FOR ECONOMICAL REUSE

(57) Abstract: Is a process intended on reducing the volumetric expansion of steel slag through hydration and carbonation of the free magnesium and calcium oxides contained in the slag. The process is initiated with the preparation of an inertization yard, where the slag will be homogenously distributed until a previously defined thickness is achieved, being, later on, aerated and dampened, which will accelerate the hydration and carbonation chemical reactions on most of the free calcium and magnesium, which are the main responsible for the volumetric expansion of the steel slag, making the slag suitable for use in road works.

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PROCESS OF INERTIZATION (DAMPENING) OF STEEL MAKING SLAG FOR ECONOMICAL REUSE

5 This invention refers to an economical process in which the steel slag can be reused, through inertization (aeration and hydratation). Specifically, this invention refers to an improvement in the steel slag recycling.

The steel alloys' manufacturing processes are well known, as well as the inherent residue generation, like mud and slag, of which the steel slag can be evidenced. Its technical application and environmentally adequate solution is the
10 objective of the development of this process.

Collection and storage of the steel slag creates various problems like handling, transportation, loading, unloading and stocking for the huge amounts of this material, each of them with its own structure for environmental protection, especially water contamination.

15 Having in mind the rigorous inspection of environment protection agencies and social and environmental consciousness, metallurgical industries began researches seeking not only to avoid environmental damage due to their residue, as well as promoting the correct technical employment of these materials, and even making some profit through the application in road paving with asphalt coating as a replacement for
20 petroleum compounds.

The LD steel slag is obtained in the pig iron to steel transformation process, on LD type converters, in which the oxides formed during the oxygen blow combine themselves with the dissolved CaO and MgO, creating the slag that is steady (stable) and distinct from the molten bath.

25 The utilization of LD slag in road pavement is well known in many countries since decades ago, and the problems that may happen in the paving using this kind of slag are well known too. Being worth of note is the volumetric expansion caused mainly by the CaO and MgO that are free from the slag, causing ruptures in the asphalt or concrete covering.

30 The term cured steel slag, commonly refers to the slag which is free from the risk of expanding, once it has been stored for a minimum period of 6 months, despite some texts affirming that the slag has to be stored for 01 a minimum (one) year, or even 02 (two) years, to be considered cured. However, the time variable is no the only responsible factor for the stabilization of the slag. The agents that cause the stabilization

of the slag is water and atmospheric air through hydration and carbonatation of the free CaO and MgO oxides, transforming them into stable hydrates and carbonates. Due to the hydraulic characteristics of the slag, rainwater, for instance, that falls on a pile of slag will react with the CaO and SiO₂ oxides, forming a film, obstructing, like this, the
 5 influx of water in the interior of the pile, slowing the curing process.

The difference between the cure conditions of the surface and the interior of the slag piles is one of the main factors that will result in problems in road paving, supposing, mistakenly, that the whole material is cured just for the fact of being stored for a minimum period of 06 months.

10 Because of this problem, which has become a worldwide matter, some alternatives to eliminate the volumetric expansion of the steel slag have been developed, achieving the inertization of the slag.

The most efficient solutions were identified in Europe and Japan, where volumetric expansion is reduced to near-zero levels. However, the cost benefit of these
 15 technologies was one of the responsible factors for making its access practically impossible in emerging economies.

KNOWN PROCESSES

PROCESS: Increase of the fusible dissolution

DESCRIPTION: Granulometry reduction

20 MOMENT OF ACTUATION: Before generation

STRONG POINTS: Low Cost

WEAK POINTS: N/A

EFFECTIVENESS (Amount of Expansion Reduction): Not defined

PROCESS: Alteration of the slagging agent

25 DESCRIPTION: Utilizing a synthetic material as fusible

MOMENT OF ACTUATION: Before generation

STRONG POINTS: Also increases the hydraulic activity of the slag

WEAK POINTS: Does not change the free MgO ratio

EFFECTIVENESS (Amount of Expansion Reduction): Low

30 PROCESS: Silica and oxygen addition

DESCRIPTION: Silica and oxygen addition to the liquid slag with a heat source

MOMENT OF ACTUATION: After the generation, with the slag in liquid state

STRONG POINTS: Reduction in the free CaO and MgO ratios below the 1% level

WEAK POINTS: High Cost

EFFECTIVENESS (Amount of Expansion Reduction): Medium

PROCESS: Granulation with water

DESCRIPTION: Abrupt cooling with water

MOMENT OF ACTUATION: After the generation, with the slag in liquid state

5 STRONG POINTS: Also increases the hydraulic activity of the slag

WEAK POINTS: Alteration in granulometry; drying needed; environmental problems

EFFECTIVENESS (Amount of Expansion Reduction): High

PROCESS: Dry granulation

DESCRIPTION: Dry abrupt cooling

10 MOMENT OF ACTUATION: After the generation, with the slag in liquid state

STRONG POINTS: Also increases the hydraulic activity of the slag; simpler than granulation with water

WEAK POINTS: Alteration in granulometry

EFFECTIVENESS (Amount of Expansion Reduction): High

15 PROCESS: Weathering

DESCRIPTION: Weather exposition – with occasional watering

MOMENT OF ACTUATION: After the generation, with the slag in solid state

STRONG POINTS: Low cost and simplicity

WEAK POINTS: Slow; Lacks a methodological definition, Heterogeneity

20 EFFECTIVENESS (Amount of Expansion Reduction): Variable

PROCESS: Open yard steam cure

DESCRIPTION: Steam injection in the slag

MOMENT OF ACTUATION: After the Generation, with the slag in solid state

STRONG POINTS: Considerable reduction in free CaO and MgO ratios

25 WEAK POINTS: High cost, particularly if there is no steam tubing available

EFFECTIVENESS (Amount of Expansion Reduction): High

PROCESS: SKAP steam cure

DESCRIPTION: Steam injection in the slag on a sterilizer

MOMENT OF ACTUATION: After the Generation, with the slag in solid state

30 STRONG POINTS: Considerable reduction in free CaO and MgO ratios

WEAK POINTS: High cost

EFFECTIVENESS (Amount of Expansion Reduction): Very high

The Economic Reuse of the Steel Slag through its inertization (aeration and hydration), is the result of researches and tests on experimental lots of LD slag,

making possible the inertization of this slag, as well as its reuse on road paving, now that its volumetric expansion is reduced to levels that do not compromise the structure and quality of these pavements.

To make the process of economical reuse of steel slag through its inertization (aeration and hydration) better visualized, two photographs are attached to this report through Figure 01. The first (A), shows a ruptured layer of asphalt because of the use of unprocessed slag, and on the second (B) shows an asphaltic layer applied over the steel slag that was inertized through the present process.

The Economic Reuse of the Steel Slag through its inertization (aeration and hydration) begins after the definition of an area to receive the slag, being prepared through topographical instructions that allow the proposed process to be carried out.

After the area is defined and adapted, it will be called inertization yard, where starts the process of unloading the slag, which will be laid through trucks and, later, through specific equipment, and distributed in homogenous way over the area until the previously defined thickness is achieved all over the area.

With the inertization yard prepared, the slag is ready to go through the process of aeration, process that starts with the movement of the slag with a leveling machine, a plough, a bulldozer or any other equipment capable of promoting the aeration of this material through its mixture, causing, subsequently, the acceleration of the carbonatation of the free magnesium and calcium oxides existing in the slag, increasing the slag's contact with atmospheric air.

After the initial movement of the material laid in this yard, representative samples of the lot are taken for volumetric expansion level (initial volumetric expansion) analysis.

Simultaneously to the aeration process, the hydration process is done, through water aspersion with a water truck, or aspersers installed on the inertization yard, arranged in a way so that all the slag is reached, accelerating the hydration reactions of the oxides contained in the slag, especially the free magnesium and calcium oxides, which are the main responsible for the volumetric expansion of the slag.

These procedures are done daily, until the soil laboratory, responsible for the expansion level analysis, decides to halt the work, based on the periodic analysis of the volumetric expansion level of the slag lot being processed.

The water volume to be used during the inertization process will depend on the characteristic of each slag lot submitted to the process, once this characteristic depends

on the type of produced steel, as well as other factors.

The ending of the inertization process of a certain lot of slag follows the control and quality criteria defined by the appropriate road standards, DNER-ES-301/97 AND DNER-ES-303/97 standards, on which the necessary amount of samples is indicated, as well as specific factors for acceptance analysis of a particular material lot (according to the example below).

SAMPLE	BEGINING OF TEST	END OF TEST	FINAL EXPANSION	MEAN EXPANSION	DEVIANCE	STANDARD DEVIANCE	Value of K	NUMBER OF TESTS
1	06/30/2003	07/14/2003	1,41	1,56	-0,15	0,18	1,31	8
2	06/30/2003	07/14/2003	1,37		-0,19			
3	06/30/2003	07/14/2003	1,50		-0,06			
4	06/30/2003	07/14/2003	1,48		-0,08			
5	06/30/2003	07/14/2003	1,70		0,14			
6	06/30/2003	07/14/2003	1,42		-0,14			
7	06/30/2003	07/14/2003	1,82		0,26			
8	06/30/2003	07/14/2003	1,77		0,21			

Maximum Value established for the Expansion = 2,0 %

Calculation of Ks = K x (Std. Deviance)

$$1,31 \times 0,18 = 0,23$$

CRITERIA

Mean Expansion + Ks < 2,0

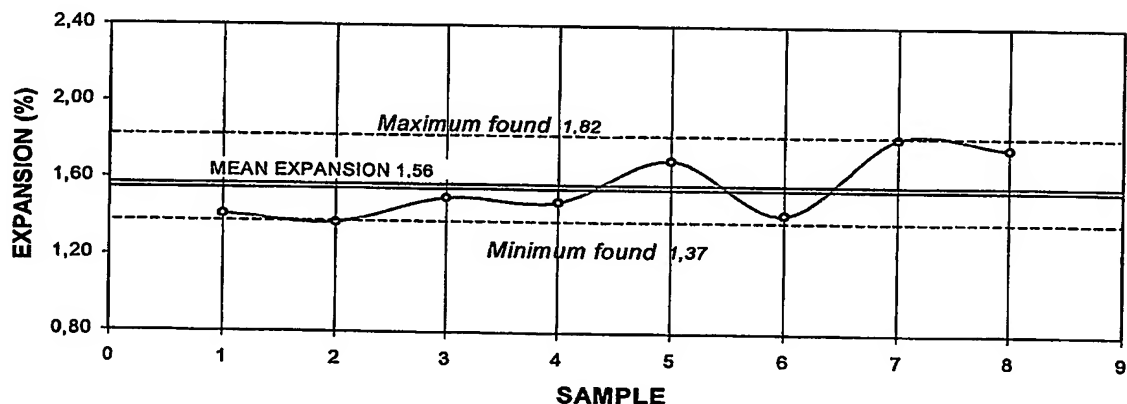
Mean Expansion + Ks > 2,0

ACCEPTED
REJECTED

$$\sigma = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n-1}}$$

FOUND VALUES

$$\text{Mean Expansion} + Ks = 1,56 + 0,23 = 1,79$$



N=# of samples	5	6	7	8	9	10	11	12	13
K	1,55	1,41	1,36	1,31	1,25	1,21	1,18	1,16	1,13

For the residual volumetric expansion verification of the inertized product, the chosen method is the "PTM-130", that was developed Pennsylvania Transportation Department (USA) and adapted by the Minas Gerais Highway Department (DER/MG).

Besides the volumetric expansion test, it is necessary to verify the granulometry, the density, the ideal humidity and the California Support Index, vital evaluation

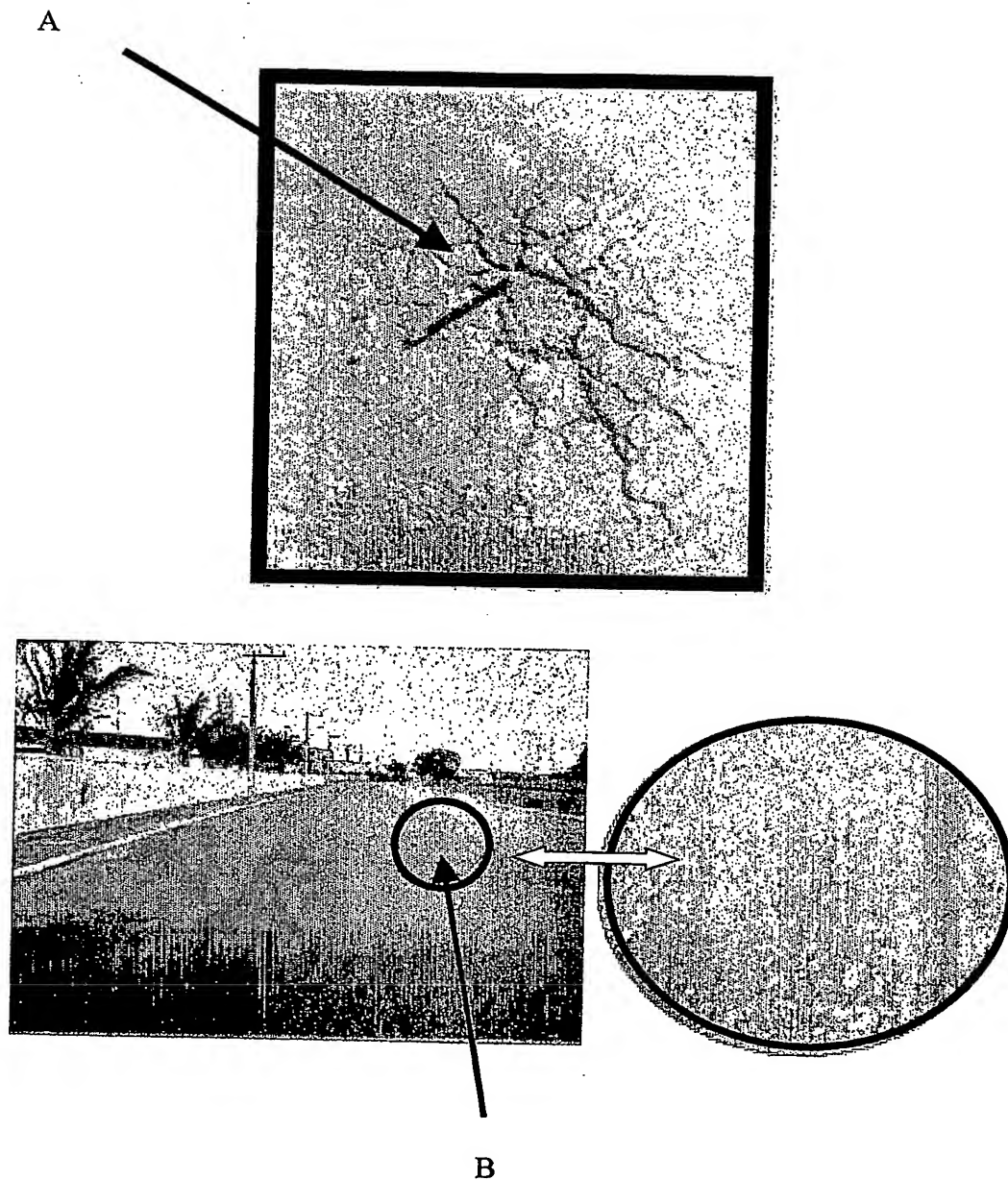
characteristics of the aggregates to be used in the execution base and sub-base for road pavements.

5 With the process of Economic Reuse of the Steel Slag through its inertization (aeration and hydratation), the LD steel slag, that has been adequately enhanced and submitted to the inertization process accordingly to the quality control criteria described above, can be used as aggregate in the execution of road work, as base and sub-base pavement element, as well as aggregate for asphaltic concrete.

CLAIMS

- 1 - ECONOMIC REUSE OF THE STEEL SLAG THROUGH INERTIZATION (AERATION AND HYDRATATION) PROCESS, characterized by the reduction of volumetric expansion in steel slag, verified on laboratory by specific tests, seeking its economical reuse in pavement base and sub-base, and asphaltic covering in road works;
- 2 - ECONOMIC REUSE OF THE STEEL SLAG THROUGH INERTIZATION (AERATION AND HYDRATATION) PROCESS, according to claim 1, characterized by inertization yard, over which the steel slag will be laid and processed;
- 3 - ECONOMIC REUSE OF THE STEEL SLAG THROUGH INERTIZATION (AERATION AND HYDRATATION) PROCESS, according to claim 1, characterized by distribution of the steel slag over the inertization yard in a homogenous way;
- 4 - ECONOMIC REUSE OF THE STEEL SLAG THROUGH INERTIZATION (AERATION AND HYDRATATION) PROCESS, according to claim 1, characterized by movement of the slag on the inertization yard using a leveling machine, a plough, a bulldozer or any other equipment capable of promoting the aeration of this material through its mixture, accelerating of the carbonatation of the free magnesium and calcium oxides existing in the slag;
- 5 - ECONOMIC REUSE OF THE STEEL SLAG THROUGH INERTIZATION (AERATION AND HYDRATATION) PROCESS, according to claim 1, characterized by initial representative sample analysis of the lot for verification of the volumetric expansion level of the steel slag (initial volumetric expansion);
- 6 - ECONOMIC REUSE OF THE STEEL SLAG THROUGH INERTIZATION (AERATION AND HYDRATATION) PROCESS, according to claim 1, characterized by hydration, through water aspersion over the slag with a water truck, or aspersers installed on the inertization yard, arranged in a way so that all the slag is reached, accelerating the hydration reactions of the oxides contained the slag, especially the free magnesium and calcium oxides, which are the main responsible for the volumetric expansion of the steel slag.
- 7 - ECONOMIC REUSE OF THE STEEL SLAG THROUGH INERTIZATION (AERATION AND HYDRATATION) PROCESS, according to claim 1, characterized by leaching and solubilisation of the steel slag, generating residues that will have other treatment.

FIGURE 01



INTERNATIONAL SEARCH REPORT

International application No.
PCT/BR 2004/000203

A. CLASSIFICATION OF SUBJECT MATTER

IPC⁷: C04B 5/00, C21C 5/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC⁷: C04B, C21C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPOQUE, WPI, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 61146745 A (NIPPON STEEL CORP) 4 July 1986 (04.07.1986) (abstract). [online] [retrieved on 27.12.2004]. Retrieved from: EPOQUE PAJ Database. <i>abstract.</i>	1, 6

X	JP 10338557 A (SUMITOMO METAL IND LTD) 22 December 1998 (22.12.1998) (abstract). [online] [retrieved on 27.12.2004]. Retrieved from : EPOQUE PAJ Database. <i>abstract.</i>	1, 6

☐ Further documents are listed in the continuation of Box C.

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* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search
27 December 2004 (27.12.2004)

Date of mailing of the international search report
7 January 2005 (07.01.2005)

Name and mailing address of the ISA/ AT
Austrian Patent Office
Dresdner Straße 87, A-1200 Vienna

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Facsimile No. +43 / 1 / 534 24 / 535

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Continuation of first sheet

Continuation No. II

Observations where certain claims were found unsearchable

(Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

Claims Nos.: 7 because they relate to subject matter not required to be searched by this Authority, namely:

Claim 7 does not specify how lixiviation is done and what the resulting product is used for.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/BR 2004/000203

Patent document cited in search report			Publication date	Patent family member(s)	Publication date
JP	A	10338557		none	
		A2			
JP	A	61146745		none	
		A2			

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Date of the actual completion of the international search
27 December 2004 (27.12.2004)Date of mailing of the international search report
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Austrian Patent Office
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Continuation of first sheet**Continuation No. II****Observations where certain claims were found unsearchable****(Continuation of item 2 of first sheet)**

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